Detection Errors on the Word The: Evidence for Reading Units Larger than Letters

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In four experiments, subjects read 100-word passages and circled instances of the letter t. Subjects missed a disproportionate number of is in the word the. Evidence was provided against explanations of this effect involving the location and pronunciation of the t in the and against an explanation in terms of the redundancy of the. Rather the high frequency of the appeared to be critical, and it was suggested that high-frequency words are read in terms of units larger than the letter.

In an experiment on letter cancellation, D. W. J. Corcoran (1966) considered the errors that subjects make in searching for instances of the letter e in a prose passage. Two interesting results were obtained in this study: (a) The letter e was missed more often in words in which e was silent than in words in which e was pronounced; and (b) the e in the word the had the greatest probability of being omitted; the probability of missing an e in the was greater than either the probability of missing a silent e or the probability of missing a pronounced e. Although the first result has received wide attention because of its implications for acoustic factors in reading, the second result has been largely ignored in the psychological literature. It is the aim of the present study to replicate, extend, and account for this neglected finding.

Corcoran provided three possible explanations for the result: (a) The pronunciation hypothesis. The e in the is normally pronounced /ə/. (b) The location hypothesis. The e in the is in the terminal position. (c) The redundancy hypothesis. The is a highly redundant word which is not scanned. Corcoran provided evidence against the first two possibilities. Words in which e was pronounced /i:/ and /i/ were more likely to be missed than words other than the in which e was pronounced /ə/. Furthermore, the e in the was much more likely to be missed than terminal es in other words. The third explanation was therefore preferred by Corcoran. However, there exists a fourth possible explanation which Corcoran did not consider but which will be considered in the present study: the unitization hypothesis. The is a word with an extremely high frequency in the language which should make it especially likely to be read as a unit or chunk rather than in terms of its component letters. Other investigators using letter detection paradigms (e.g., Johnson, 1975; Wheeler, 1970) have argued that words are read in terms of units larger than letters. However, there has been considerable dispute and confusion concerning these studies as well as the analogous studies dealing with speech perception (e.g., Healy & Cutting, in press; McNeill & Lindig, 1973).1 In fact, investigators have argued that the basic units of reading are larger than letters

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1 Although the unitization question in the auditory modality is superficially analogous to that in the visual modality, the two questions are not totally parallel. Because of the apparent abstractness of phonemes, the question in the auditory modality seems to be whether phonemes can ever be perceptual units. On the other hand, in the visual modality, it is understood that letters can be perceptual units under appropriate conditions. The question of interest in that case is whether there are any conditions where larger perceptual units are employed.
both on the basis of superior performance on letter detection in word contexts (e.g., Wheeler, 1970) and on the basis of inferior performance on letter detection in word contexts (e.g., Johnson, 1975). Various differences in the designs of these studies have permitted such seemingly contradictory results and have been largely responsible for the present confusion. For example, there are critical differences across studies in the dependent variables considered (errors versus response latencies), display time (see Johnson, 1975), and placement of the target cue (precue versus postcue; see, e.g., Estes, Bjork, & Skaar, 1974).

The present study will reconsider whether words are ever read in units larger than letters. Since different strategies may be employed in different detection paradigms and thereby lead to different results (see Johnson, 1975, for a similar argument), the present study will employ the detection paradigm of Corcoran (1966), described above, which seems to approach the normal reading situation more closely than do the other letter detection paradigms reviewed above. A valuable route toward settling the question of whether reading units are ever larger than letters might be to consider the variables expected to influence the size of the reading unit and to determine if letter detection is influenced by these variables. That strategy will be employed in the present study where, as argued above, word frequency will be considered as a variable which should influence the size of the reading unit.

**Method**

**Subjects.** Twenty-four male and female Yale University undergraduates, who were taking a course in introductory psychology, participated in this experiment for course credit.

**Design and materials.** Two 100-word passages, typed on separate sheets of paper, were employed. One passage, hereafter referred to as the "prose passage," was taken directly from the novel The Lord of the Flies by William Golding. This passage included 40 ts altogether, 11 of them occurring in the word the. The second passage, hereafter referred to as the "scrambled-letter passage," was derived from the first. The ts, punctuation marks, and "interword" spaces were kept in the same locations, but the locations of the other letters were changed. The letters in each of the 20 consecutive five-letter strings were the same in the two passages, but the order differed. Unlike the prose passage, the order of the letters in every five-letter string was random.

**Procedure.** The subjects were tested individually in a session which included other experimental testing. Each subject was given Xerox copies of both passages; the order of presentation of the passages was counterbalanced across subjects. The subjects were told to read each passage at their normal reading speed and to encircle each instance of the letter t with a pen or pencil. The subjects were told that if they ever realized that they missed a t in a previous word, they should not retrace their steps to encircle the t, and that they were not expected to get every t so they should not slow down their reading speed in order to be overcautious about getting the ts.

In addition to the search task, the subjects were given the task of timing themselves. A stopwatch was provided for that purpose.

**Results and Discussion**

The results of the present experiment are summarized in Table 1, which includes for the two passages the mean and standard error of the mean for the number of total errors, the reading time in seconds, and the conditional percentage of errors in "the locations" given an error. A t in a the location occurs in the word the in the prose passage or in the corresponding location in the scrambled-letter passage. There is a large difference in total errors on the two passages. Each of the 24 subjects missed more ts in the prose passage than in the scrambled-letter passage, t(23) = 7.58, p < .001. However, this finding involves a speed-accuracy trade-off since subjects were faster at reading the prose passage than the scrambled-letter passage, t(21) =
6.34, \( p < .001 \). A trivial explanation for this speed-accuracy trade-off is that reading time is reduced by the amount of time it takes to circle a letter whenever a letter detection error is made. However, a more interesting possibility is that the speed-accuracy trade-off may reflect a strategy difference across conditions. Subjects may pay more attention to the reading task and less attention to the detection task in the prose passage than in the scrambled-letter passage.

A strategy difference of some sort may also account for the discrepancy between the present results and those of an analogous experiment by Krueger (1970b, Experiment 1) involving a visual search task. As in the present study, Krueger found that subjects searched for target letters more rapidly through words than through nonwords, but he did not find the speed-accuracy trade-off observed here. In Krueger's study subjects made slightly, but not significantly, more errors on nonwords than on words. The fact that a speed-accuracy trade-off was found in the present experiment but was not found in Krueger's experiment can be easily understood in terms of the trivial explanation of the speed-accuracy trade-off discussed above. Although subjects could trade off accuracy for speed by reducing the number of detection responses made in the present situation, the subject could not do so in Krueger's task since the subject made only one detection response on every trial in that situation.

However, the above explanation cannot account for the fact that the word context aided letter detection in Krueger's situation but hindered letter detection accuracy in the present task. Although there are many differences between the two experimental situations, perhaps the most critical difference involves the instructions to the subject. Reading rather than detection was stressed in the present experiment (see above), whereas subjects in Krueger's experiment were told that they should "search for the target letter as quickly as possible, but not at the expense of accuracy" (p. 392). This difference in instructions could have led to a difference in the size of the reading unit employed by subjects in the two tasks. (Note that Johnson, 1975, likewise referred to a possible difference in the size of the reading unit to account for a similar discrepancy between his results and those of other letter detection paradigms.) Since reading was stressed in the present study, subjects in the present task, in accordance with the unitization hypothesis, may have chosen to employ the largest reading units available to them, which might have been larger than letters in the prose passage but not in the scrambled-letter passage. On the other hand, since Krueger's instructions stressed letter detection, subjects in that task may have chosen to employ letters as reading units, even in the case of word passages. Certainly subjects would be expected to make more letter detection errors when they employ reading units larger than the letter than when they employ letters themselves as reading units. On the basis of these assumptions, more letter detection errors would be expected in the prose passage than in the scrambled-letter passage of the present experiment, but little difference in errors would be expected be-

<table>
<thead>
<tr>
<th>Experiment</th>
<th>Total errors</th>
<th>Reading time (in sec)</th>
<th>% errors in the locations given error</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Prose</td>
<td>6.9</td>
<td>47</td>
<td>62</td>
</tr>
<tr>
<td></td>
<td>( M )</td>
<td>( \bar{S}_M )</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>1.5</td>
<td>55</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td>( M )</td>
<td>( \bar{S}_M )</td>
<td>2</td>
</tr>
</tbody>
</table>

| 2 Scrambled words | 5.3          | 53                    | 67                                  |
|                  | \( M \)      | \( \bar{S}_M \)       | 2                                   |

| 3 The            | 5.4          | —                     | 52                                  |
| Thy              | \( M \)      | \( \bar{S}_M \)       | 4                                   |

TABLE 1

MEAN AND STANDARD ERROR OF MEAN FOR TOTAL ERRORS, READING TIMES, AND CONDITIONAL PERCENTAGES FOR PASSAGES OF EXPERIMENTS 1, 2, AND 3
between the two passages in Krueger's study, as was found to be the case.

Although the results concerning errors in the present experiment and in that of Krueger's study can be explained in this way, an explanation must still be provided for Krueger's finding of faster reading times for his nonword passages. Krueger's own redundancy explanation applies here and does not seem to contradict the assumptions made above. According to this explanation, subjects who are reading with letters as units would be expected to read more quickly when these units are redundant, as they are in the word passages but not in the nonword passages.

In any case, a speed-accuracy trade-off should not influence the conditional percentage of errors in the locations given an error, which is the critical dependent variable of the present experiment and was not considered by Krueger (1970b). By chance alone the conditional percentage of errors in the locations should be 27.5, since 11 of the 40 is are in the locations. The mean conditional percentage is significantly greater than chance for the prose passage, \( t(23) = 8.63, p < .001 \), and is significantly less than chance for the scrambled-letter passage, \( t(15) = 4.50, p < .001 \).

The large conditional percentage of errors in the word the for the target letter t is consistent with the disproportionate number of errors in the word the found by Corcoran (1966) for the target letter e. Corcoran's location and pronunciation hypotheses are weakened by these results since the letter t in the word the does not share either pronunciation or location with the letter e. It may be argued, however, that pronunciation is still a potential factor since the letter t is not pronounced /t/ in the as it is usually. Both the redundancy and unitization hypotheses are consistent with the finding of a large percentage of errors in the on the letter t since both of these hypotheses are neutral with respect to the particular target letter employed.

The observation that the conditional percentage of ts missed in the locations is greater for the prose passage than the scrambled-letter passage is inconsistent with the location hypothesis since the ts are in the same locations with respect to the word boundaries in the two passages. However, this finding is consistent with the pronunciation hypothesis since the ts in the the locations would be pronounced differently in the two passages. Similarly, this finding is consistent with the redundancy and unitization hypotheses since only in the prose passage do the ts in the the locations fall within letter strings that are redundant or that might be expected to act as reading units. Since the present data cannot discriminate between the pronunciation, redundancy, and unitization hypotheses, the next experiments were run in order to provide further tests of these hypotheses.

**Experiment 2**

The present experiment was run in order to test further Corcoran's (1966) redundancy hypothesis. A scrambled-word passage was employed because the word the should not be redundant in such a passage.

**Method**

**Subjects.** The same 24 subjects were employed in this experiment as in Experiment 1.

**Design and materials.** A 100-word passage, typed on a sheet of paper, was constructed for the present experiment. Hereafter this passage will be referred to as the "scrambled-word passage." This passage was derived from the prose passage. The same words were employed, and the punctuation marks and the thes were kept in the same locations in the two passages, but the locations of the other words were changed. Unlike the prose passage, the other words in the scrambled-word passage were in a random order.

**Procedure.** The subjects were tested on the present passage in conjunction with the two passages from Experiment 1. The order of presentation of the three passages was counterbalanced across subjects. The procedure and instructions for all three passages were the same.

**Results and Discussion**

The results of the present experiment are summarized in Table 1, where they are compared to the results of Experiment 1. Both the speed and the accuracy on this passage fall midway between those on the other two conditions. The difference in errors between the prose and scrambled-
word passages is significant, \( t(23) = 2.65, p < .02 \), as is the difference in errors between the scrambled-word and scrambled-letter passages, \( t(23) = 5.57, p < .001 \). Similarly, the difference in times between the prose and scrambled-word passages is significant, \( t(21) = 3.83, p < .001 \), but the difference in times between the scrambled-word and scrambled-letter passages does not reach standard levels of statistical significance, \( t(21) = 1.89, .10 > p > .05 \). These indications of a speed-accuracy trade-off are consistent with the trivial explanation described above as well as with the more interesting possibility that there is a strategy difference across conditions. Subjects may pay more attention to the reading task and less attention to the detection task as the passage increases its semblance to prose.

The conditional percentages of errors in *the* locations are more critical since they are not affected by the speed-accuracy trade-off. The mean conditional percentage for the present passage is slightly larger than that for the prose passage, but not significantly so, \( t(21) = 1.39, p > .10 \). This finding is inconsistent with the redundancy hypothesis. Since *thes* in the scrambled-word passage are less redundant than those in the prose passage, the redundancy hypothesis would predict a smaller conditional probability for the scrambled-word passage.

**Experiment 3**

The present experiment was run in order to provide a further test of the pronunciation hypothesis. The word *thy*, where *t* is pronounced in the same manner as it is pronounced in the word *the*, is compared with the word *the* in a detection task.

**Method**

**Subjects.** One hundred twenty-two male and female Yale University undergraduate students who were taking a course in introductory psychology were run as subjects in a group experiment conducted in the classroom.

**Design and materials.** The scrambled-word passage employed in Experiment 2 was again used in the present experiment where it will be referred to as the "*the* passage." In addition, a new passage, referred to as the "*thy* passage," was constructed so that it was identical to the scrambled-word passage except that every instance of the word *the* was replaced by the word *thy*.

**Procedure.** The same instructions and procedure were employed in the present experiment as had been employed in Experiments 1 and 2 except that subjects were not told to time themselves. Each subject was shown both passages; 60 subjects were given the *the* passage first, and 62 subjects were given the *thy* passage first.

**Results and Discussion**

The results of the present experiment are summarized in Table 1, which includes for the two passages the mean and the standard error of the mean for the number of total errors and the conditional percentage of detection errors on words in *the* locations. An error in a *the* location in the present experiment can occur in the word *the* in the *the* passage or in the word *thy* in the *thy* passage. The results for the *the* passage essentially replicate those of Experiment 2, but the results for the *thy* passage show a different pattern. The total number of errors is greater in the *the* passage than in the *thy* passage, \( t(121) = 3.42, p < .001 \). More importantly, the mean conditional percentage for the *thy* passage is much lower than that for the *the* passage, \( t(98) = 13.47, p < .001 \). These results greatly weaken the pronunciation hypothesis since the *t* in the words *the* and *thy* are pronounced in the same way. In addition, these results tend to refute any explanation of the preponderance of errors on the word *the* based on word length or location of the *t* since these characteristics for *the* are also shared with *thy*. However, other interpretations of these results are possible. For example, it is possible that the archaic quality of the word *thy* might have led the subject to pay an undue amount of attention to it, thereby reducing the number of detection errors made on it.

**Experiment 4**

This experiment is designed to provide a further test of the unitization hypothesis, according to which the high frequency of the word *the* rather than its other char-
characteristics causes it to be the locus of many detection errors. In this experiment word frequency was manipulated directly.

**Method**

**Subjects.** The same 122 subjects employed in Experiment 4 were employed in the present experiment. The present experiment was conducted immediately after the completion of Experiment 3.

**Design and materials.** Two new passages of 100 scrambled words each were constructed. The passages had the same punctuation as those employed earlier; only the words differed. The words employed were taken from a list of nouns composed by Paivio, Yuille, and Madigan (1968). Each passage included 50 high-frequency words (AA on the Thorndike–Lorge scale, 1944) and 50 low-frequency words (5 or less on the Thorndike–Lorge scale). There were 40 ts in each passage; 20 of these ts occurred in high-frequency words and 20 in low-frequency words. The words employed were chosen from the list of Paivio et al. with the following constraint: For every high-frequency word chosen, a low-frequency word was chosen which was the same length as the high-frequency word. Wherever a t, if any, occurred in the high-frequency word, a t occurred in the same location in the corresponding low-frequency word. For example, the high-frequency word plant was matched with the low-frequency word yacht.

The two passages included the same words; they differed only in the order of the words. Whenever a high-frequency word containing a t occurred in one passage, its low-frequency mate occurred in the same location on the other passage and vice versa. Thus, for example, plant on one passage was replaced by yacht on the other passage and yacht was replaced by plant. The order of the words was otherwise pseudorandom and the same for both passages.

**Procedure.** The same instructions and procedure held for the present experiment as for Experiment 3; hence the instructions were not repeated between experiments. Rather, subjects were told at the start of the session to go on to the passage for the present experiment immediately after they had completed the passages for Experiment 3, continuing with the same task.

Sixty-one subjects were given one of the two passages for the present experiment, and the other 61 subjects were given the other passage.

**Results and Discussion**

The results of the present experiment are summarized in Table 2 in terms of the mean and standard error of the mean for the number of detection errors separated by frequency class. Significantly more errors were made on high-frequency words than on low-frequency words; both summed over items with subjects as the random variable, $t(121) = 5.27, p < .001$, and summed over subjects with items as the random variable, $t(19) = 2.78, p < .01$. The difference in frequency cannot be attributed to a difference in part of speech since all words employed were nouns. Similarly, the observed difference cannot be due to word length, location of t within the word, or location of the word on the page since each of these three variables was controlled in the present experiment. Furthermore, the observed difference cannot be attributed to the frequency of the words surrounding the target rather than to the frequency of the target word itself since word frequency was varied within rather than between passages.

Although the effect of word frequency is not large, it seems to be of sufficient magnitude to explain the previously observed large proportion of errors on the word the since the is the most frequent word in the English language and is considerably more frequent than the nouns employed as high-frequency words in the present experiment. However, the possibility has not been ruled out that the preponderance of errors on the word the is due to other factors as well as to word frequency.

**Summary and Conclusions**

Corcoran (1966) observed that subjects make a disproportionate number of detection errors on the word the when searching for the letter e. Four hypotheses have been proposed to account for this finding: (a) the location hypothesis, (b) the pronunciation hypothesis, (c) the redundancy hypothesis, and (d) the unitization hypothesis. The present study provides evidence against the first three hypotheses. Evidence against the location

**TABLE 2**

<table>
<thead>
<tr>
<th>Frequency class</th>
<th>Number of errors M</th>
<th>SEM</th>
</tr>
</thead>
<tbody>
<tr>
<td>High</td>
<td>4.18</td>
<td>.33</td>
</tr>
<tr>
<td>Low</td>
<td>3.12</td>
<td>.29</td>
</tr>
</tbody>
</table>


hypothesis came from the results of the scrambled-letter condition of Experiment 1 and the thy condition of Experiment 3, where it was shown that ts placed in the same locations as in the word the but in different words are not missed so frequently. Evidence against the pronunciation hypothesis came from the thy condition of Experiment 3 where it was shown that ts in the word thy, which are pronounced in the same way as in the, are not missed as frequently as are ts in the word the. Evidence against the redundancy hypothesis came from Experiment 2 where it was shown that reducing the redundancy of the word the by placing it in a scrambled-word passage did not reduce the frequency with which detection errors were made on the word the.

In contrast to the location, pronunciation, and redundancy hypotheses, the unitization hypothesis cannot be rejected on the basis of the data of the present study. In addition, indirect support for the unitization hypothesis came from Experiment 4 where it was shown that frequent words, which would be expected to be read in terms of larger units, show more detection errors than infrequent words. More direct support for this hypothesis is needed before it can be fully accepted. Nevertheless, on the basis of the present study, it seems reasonable to conclude tentatively that we do not read frequent words such as the in terms of their component letters but rather in terms of larger units, perhaps the words themselves, spelling patterns (Gibson, 1965), or vocalic center groups (Spoehr & Smith, 1973). The present study thus provides an answer to the more general question of whether there are any conditions where units larger than letters are employed in reading. On the basis of the comparison of the present results with the conflicting results of Krueger (1970b), it was suggested that larger units are employed with instructions stressing reading rather than letter detection. Furthermore, on the basis of the results from Experiment 4, it was suggested that larger units are employed with words of high frequency in the language.

In conclusion, it is important to note that evidence such as that provided here for the size of the reading unit should not be taken necessarily as evidence for the size of the perceptual unit employed in reading. Just as many of the word-context effects found in other detection studies have been localized at nonperceptual levels of processing (Estes, 1975), the present effects do not necessarily reflect perceptual processes per se. Rather, the present results may merely indicate that subjects respond, perhaps via subvocalization, to frequent words in units larger than the letter. This explanation in terms of response units rather than perceptual units seems reasonable in light of the evidence described above (Corcoran, 1966) that subjects scan an acoustic image of the material when searching for letters in a prose passage. Evidence from Krueger (1970a) on the effect of acoustic confusability suggests that his visual search task may also reveal more about the subject's response units than his perceptual units. In addition, a parallel conceptual problem exists for those investigators who wish to make conclusions about the units of speech perception on the basis of speed of detectability in auditory monitoring tasks. As several authors have noted (see, e.g., Foss & Swinney, 1973; Healy & Cutting, in press; Treisman & Squire, 1974), the order of processing different linguistic levels for speech perception may not be the same as the order of accessing those levels in a detection task. Hence any evidence from auditory monitoring tasks concerning the relative ease of detecting targets from various levels of the linguistic hierarchy does not necessarily pertain to the level of the unit employed in perception. Before firm conclusions can be reached concerning the level of the perceptual unit both in the auditory modality and in the visual modality, tasks must be considered which reflect perceptual processes more directly than do any of the detection tasks reviewed here.

REFERENCES


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